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Effect of lubricant type on deep drawing ratio and drawing force during cylindrical cup deep drawing

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EFFECT OF LUBRICANT TYPE ON DEEP DRAWING RATIO AND DRAWING FORCE DURING CYLINDRICAL CUP DRAWING

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تأثير نوع مادة التزيت على معامل السحب وقوى التشكيل لعمليه سحب الكؤوس الاسطوانيه

ملخص

تستخدم تقنية السحب العميق للكوب الأسطواني في عمليات التصنيع المختلفة. على سبيل المثال ، يتم استخدامه في صناعة السيارات لتصنيع قطع غيار السيارات. كما أنها تستخدم في صناعة الأدوات المنزلية. تستخدم المزلقات في تشكيل المعادن ، وخاصة السحب العميق ، لتقليل الاحتكاك بين الأداة وقطعة العمل. نتيجة لذلك ، يقلل التشحيم من الطاقة المتكونة وخطوات التشكيل ، ويزيد من نسبة الرسم وعمر الأداة ، مع منع التشويش والتشنج وأضرار السطح التي تلحق بالمنتجات. في هذا البحث ، كان الغرض الرئيسي هو زيادة نسبة السحب العميق وتقليل قوة السحب بزاوية القالب والحامل الفارغ ، والتحقيق في تأثير التشحيم على عملية السحب العميق. القوة المطلوبة وجودة الكؤوس المسحوبة. تم استخدام نوعين مختلفين من مواد التشحيم المعدنية والصلبة بالإضافة إلى زاويتين مختلفتين للقالب بين القالب والحامل الفارغ. أظهرت النتائج أن نسبة السحب المحددة زادت من 1.75 إلى 2.175 دون انهيار ، وأظهر زيت التشحيم تحسينًا أفضل لنسبة السحب وقلل من قوة السحب القصوى.

Abstract

Cylindrical cup deep drawing technology is used in various manufacturing processes. For example, it is used in the automotive industry to manufacture auto parts. It is also used in the manufacture of household items. Lubricants are used in metal forming, especially deep drawing, to reduce friction between the tool and the workpiece. As a result, lubrication reduces forming energy and forming steps, increases the drawing ratio and tool life, while preventing galling, seizure and surface damages to the products. In this paper, the main purpose was to increase the deep drawing ratio and reduce the drawing force by angling the die and blank holder, and investigated the effect of lubrication on the deep drawing process. The force required and quality of deep-drawn cylindrical steel cups. Two different lubricants mineral and solid lubricant were used as well as two different die angles between the die and the blank holder ($\alpha = 0^o$ and 15^o). The results shows that The Limit drawing ratio increased from 1.75 to 2.175 without failure, The oil lubricant shows better enhancement of the drawing ratio and reduced the maximum drawing force.

1. INTRODUCTION

The deep drawing process is one of the most important technologies in modern manufacturing in terms of production capacity, energy consumption and process improvement potential [1,2]. Various factors can lead to product failure in the deep drawing process [3,4]. This failure usually manifests as wrinkle, tears, earing, and fractures. These studies included a description of material properties, tool design, and service factors such as blank holder load, friction coefficient, draw ratio, and maximum draw force. Careful control of these parameters can reduce the likelihood of drawing part failure [5].

Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch. The process is considered "deep" drawing because the depth of the drawn part exceeds its diameter. The Limiting drawing ratio (LDR) is an indicator of material formability in deep drawing. When the blank is pulled inward radially, the flange undergoes radial tension and circumferential compression [6].

The latter can cause flange wrinkles when the draw ratio is high or when the cup diameter to thickness ratio is high. The blank holders usually apply sufficient pressure to the sheet to prevent wrinkles [7]. The stress on the cup wall caused by the punching force creates a radial tensile stress on the flange being pulled. Therefore, if the cup is stretched at a larger stretching ratio, more radial stress will be generated at the flange and more cup wall tensile stress will be required. This tension in the cup wall also provides bending and relaxation across the radius of the die. In addition, the tension in the cup wall should help overcome the frictional resistance between the flange and the tool radius. Since the tensile stress of the cup wall is limited by the maximum tensile strength of the material, the possible draw ratios for deep drawing are usually about 2.1 or 2.2 in special drawing processes such as hydro-forming [8], hydro-mechanical forming [9], counter pressure deep drawing [10], hydraulic pressure-augmented deep drawing [11], etc. These processes are relatively slow (compared to the deep drawing or redrawing process) and the draw ratios are limited to 3.5 or 4 at most. However, a conventionally-drawn cup can be redrawn twice or more to obtain draw ratios of the order of 5, 6 or even larger values. The LDR has increased without failure by giving an angle to die and blank holder, blank holder force gives an optimum value at $\alpha = 15^{o}$ [12]. Fig.1. Shows the sketch of the deep drawing die.

Lubricants are used in metal forming, especially deep drawing, to reduce friction between the tool and the workpiece. As a result, lubrication reduces forming energy and forming steps, increases the LDR and tool life, while preventing galling, seizure and surface damages to the products. In addition, the disposal of large amounts of waste lubricating oil is a serious environmental and economic problem. Furthermore, the use of lubricants in metal forming processes requires cleaning of the forming parts; it is usually washed several times during the production steps in multi stage-forming as redrawing processes. Therefore, manufacturers have developed a variety of green manufacturing strategies under laboratory conditions. To avoid the lubricants harmful implications, a novel method was suggested and presented [13] for free drawing without using of lubricants by controlling the important variables and by means of a new macro structured tool design, claiming that the new tool structure enables the control of friction forces as well as the material flow. To avoid the pollution problems to the environment, an environmentally friendly lubricant was suggested [14]. The desired friction conditions at the blank-die interface surfaces are different from those at the blank-punch interface surfaces. While low friction at the surfaces of the blank-die interface facilitates the flow of the blank metal, dry friction between the punch and blank is necessary to increase the frictional force. Therefore, two different lubricant types; engine oil (5W-40) and solid lubricant (Molybdenum disulfide MOS_2) have been used to perform lubricating action between matting surfaces of the blank-die interface, the effect of lubricant types on the LDR, the maximum drawing force were presented and discussed.

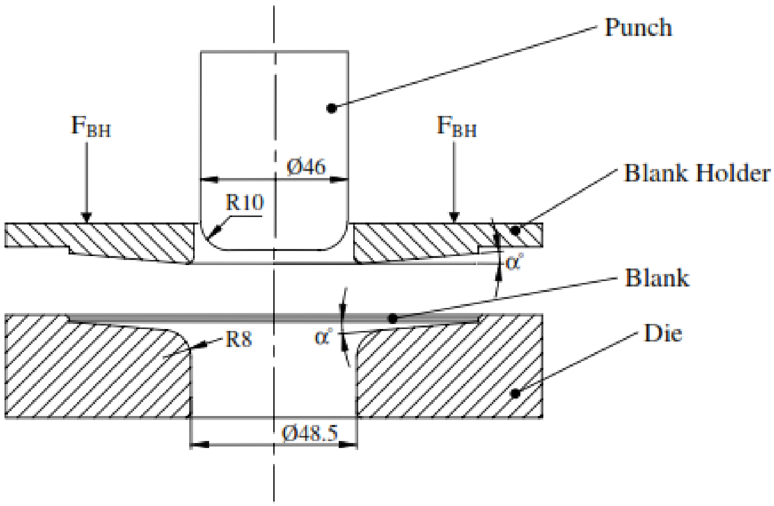

Figure1. Schematic deep drawing die.

2. EXPERIMENT

The deep drawing process was performed using the deep drawing set shown in Fig. 1 which designed and manufactured for this purpose. The die, punch and blank holder are all made of special tool steel (210CrW12: 2%C and 12%Cr with Tungsten and Vanadium addition to improve wear resistance) were used in the experimental work. The punches were hardened by heating at 980^o C under vacuum and quenching in oil; its hardness thus attained a value of 65 Rockwell C.

Fig. 2 shows a 3D die set for deep drawing of cylindrical cups. The blank was 1 mm thick stainless steel circular disc of different diameter increment of 2 mm by using turning machine, to obtain a range (1.3 - 2.6) of LDR, The LDR value determined by performing a series of deep drawing operation by varying the blank diameter.

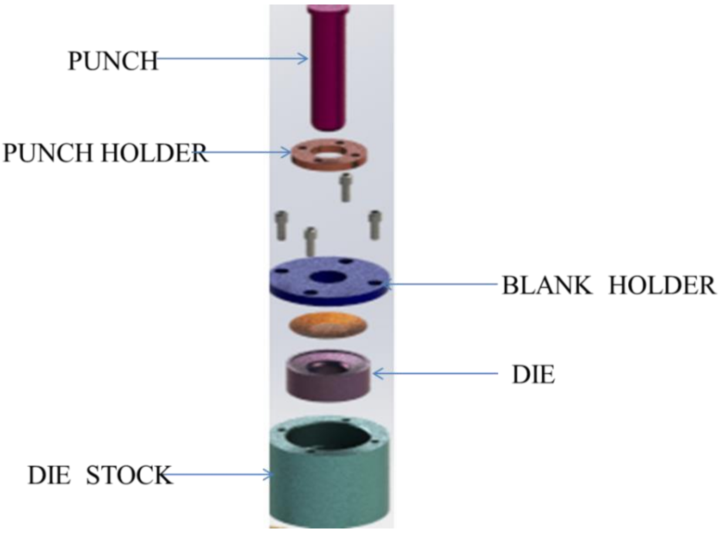

Figure 2. Die set for deep drawing of cylindrical cup.

The experimental work was carried out by means of 16-ton hydraulic press, as shown in the Fig. 3. To investigate the punching force, a load cell was adhered on the drawing die. To compute the effect of the punch force, a load cell (20 ton) connected to a digital screen is used. The blank is placed between the die and the holder. 5 gram of each lubricant is applied in the blank-die interface to facilitate the flow of the blank metal and then deformed by the punch by pushing the sheet into the die, eventually forming the shape of the die. By fixing the metal plate between the die and the blank holder before processing begins, this prevents the formation of undesired deformations such as wrinkles.

Figure 3. Experimental apparatus mounted on a hydraulic press.

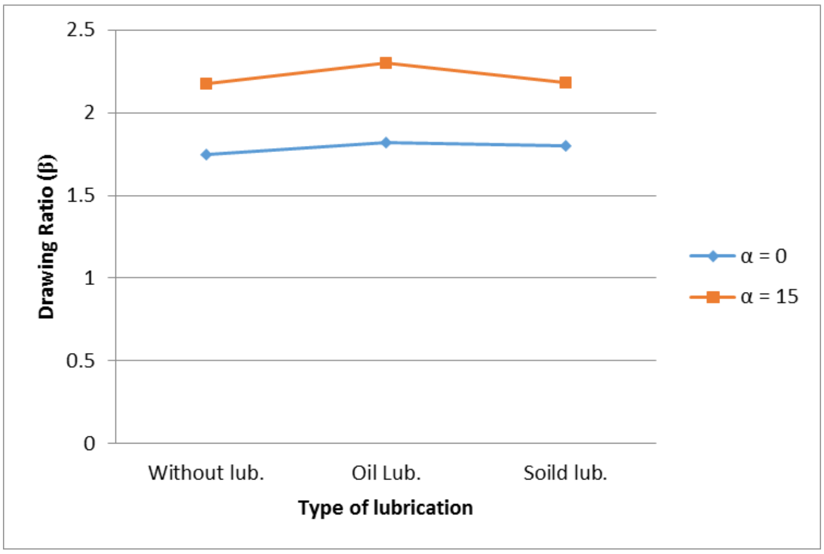

Figure 4. Effect of lubrication materials on LDR (ß).

3. RESULTS AND ANALYSIS

This section describes the effect of the addition of the two types of lubricants on the drawing ratio. The maximum drawing force and the influence on deep drawing ratio of α angle are presented and discussed.

3.1 Effect of lubrication materials on the LDR

Fig. 4. shows that when the angle α has increased, the deep drawing ratio has increased. During the experiments, when α is 0, limit deep drawing ratio is β= 1.75; However, when α is increased to 15o, ß has been increased up to 2.175. The effect of lubrication type on the drawing ratio is very slight or no difference between the three types of lubrications.

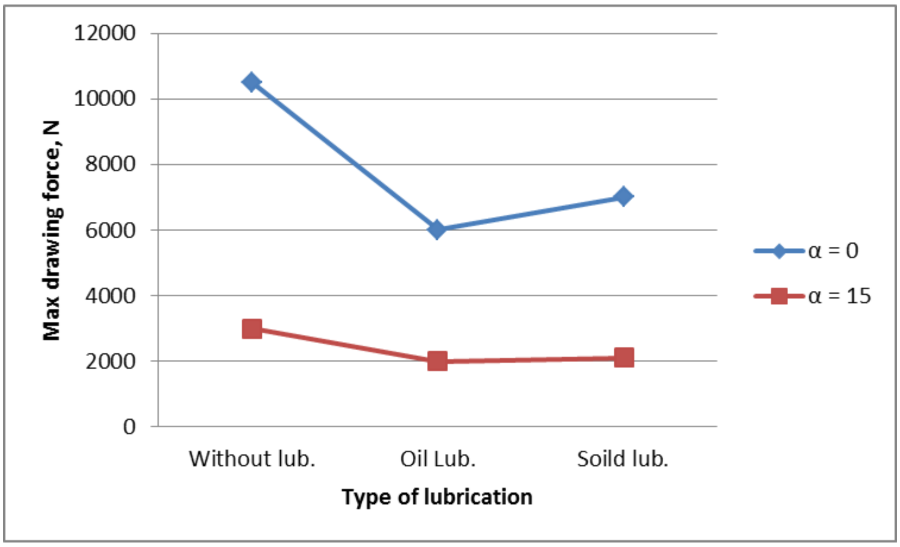

Figure.5 Effect of lubrication materials on maximum drawing force at constant β=1.75.

3.2 Effect of lubrication materials on maximum drawing force

Fig. 5 shows the effect of lubrication materials on maximum drawing force. The maximum drawing force is decreased by increasing α angle for constant value of limit drawing ratio β=1.75. Applying different lubracant type reduces the maximum drawing force, due to the easy flow of the sheet metal into the die cavity.

4. CONCLUSIONS

Based on the results of the experimental work, it can be concluded that:
-The Limit drawing ratio, based on the angle between the die and the blank holder, increased from 1.75 to 2.175 without failure.
-The Lubricant reduced the maximum drawing force and slightly increased the LDR.
-The oil lubricant shows better enhancement of the drawing ratio, therefore it is recommended for deep drawing of cylindrical cup compared to dry and solid lubricants.

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